



**University of
Zurich^{UZH}**

**Zurich Open Repository and
Archive**

University of Zurich
University Library
Strickhofstrasse 39
CH-8057 Zurich
www.zora.uzh.ch

Year: 2016

Success of 6-mm Implants with Single-Tooth Restorations: A 3-year Randomized Controlled Clinical Trial

Sahrman, P ; Naenni, N ; Jung, R E ; Held, U ; Truninger, T ; Hämmerle, C H F ; Attin, T ;
Schmidlin, P R

Abstract: The aim of the study was to test whether implants of 6 mm in length perform equally well as 10-mm implants in terms of survival and marginal bone-level changes when supporting single crowns. Patients with a posterior single-tooth gap were randomly allocated to either the placement of a 6-mm (test) or 10-mm implant (control). The treatment protocol allowed for internal sinus lift but not for lateral bone augmentation. After a healing period of 10 wk, implants were loaded with screw-retained single crowns. Survival rates, number of pockets ≥ 5 mm, and bleeding-on-probing were assessed clinically. The change of marginal bone level and crown-to-implant ratios were analyzed by 2 examiners. Longitudinal intragroup analyses for marginal bone levels were performed applying the Wilcoxon signed rank test. Intergroup differences at baseline and at 3 y were compared using the Mann-Whitney U test. The effect of implant length and crown-to-implant ratio on changes of marginal bone level also was determined. Of 94 implants placed (47 test and 47 control), 78 implants (40 test and 38 control) were available for follow-up examination at 3 y of loading. One test implant was lost during the second year. Hence, implant survival was not significantly different between the 2 groups after 3 y (98% test; 100% control). We found no significant change in the crestal bone level from baseline to 3 y for test and control implants with -0.19 ± 0.62 mm and -0.33 ± 0.71 mm, respectively. The intergroup difference was not significant. Crown-to-implant ratios were not associated with a statistically significant difference in marginal bone loss. However, the number of sites with pockets ≥ 5 mm was significantly higher in the test group. Based on the 3-y assessment, the use of 6-mm implants can be considered a viable option when reconstructing posterior single tooth gaps (German Clinical Trials Registry: DRKS00006290).

DOI: <https://doi.org/10.1177/0022034516633432>

Posted at the Zurich Open Repository and Archive, University of Zurich

ZORA URL: <https://doi.org/10.5167/uzh-128476>

Journal Article

Accepted Version

Originally published at:

Sahrman, P; Naenni, N; Jung, R E; Held, U; Truninger, T; Hämmerle, C H F; Attin, T; Schmidlin, P R (2016). Success of 6-mm Implants with Single-Tooth Restorations: A 3-year Randomized Controlled Clinical Trial. *Journal of Dental Research*, 95(6):623-628.

DOI: <https://doi.org/10.1177/0022034516633432>

**Success of 6mm implants with single tooth restorations:
A 3 year randomized controlled clinical trial**

Sahrman P^{1*}, Naenni N^{2*}, Jung RE², Held U³, Truninger T², Hämmerle CHF², Attin T¹,
Schmidlin PR¹

Key words:

Dental Implants, Alveolar Bone Loss, Survival, Dental Radiography, Peri-Implantitis

Running title: Short versus Long Implants

Address for correspondence: Philipp Sahrman, Dr. med. dent.

Clinic of Preventive Dentistry, Periodontology and
Cariology

Center of Dental Medicine, University of Zurich

Plattenstrasse 11

CH-8032 Zurich, Switzerland

Phone: +41 44 634 34 12

Fax: +41 44 634 43 08

e-mail: philipp.sahrman@zzm.uzh.ch

¹ Clinic of Preventive Dentistry, Periodontology and Cariology,

Center of Dental Medicine, University of Zurich, Zurich, Switzerland

² Clinic of Fixed and Removable Prosthodontics and Dental Material Science,

Center of Dental Medicine, University of Zurich, Zurich, Switzerland

³ Horten Centre for Patient-oriented Research and Knowledge Transfer,

University of Zurich, Zurich, Switzerland

*Authors indicated with an asterisc contributed to the same extent as first authors

Abstract

The aim of the study was to test whether implants of 6mm length perform equally well as 10mm implants in terms of survival and marginal bone level changes when supporting single crowns. Patients with a posterior single tooth gap were randomly allocated to either the placement of a 6mm (test) or 10mm implant (control). The treatment protocol allowed for internal sinus lift, but not for lateral bone augmentation. After a healing period of 10 weeks, implants were loaded with screw-retained single crowns. Survival rates, number of pockets ≥ 5 mm, and bleeding-on-probing were assessed clinically. The change of marginal bone level and crown-to-implant ratios were analyzed by two examiners. Longitudinal intra-group analyses for marginal bone levels were performed applying the Wilcoxon signed rank-test. Inter-group differences at baseline and at 3y were compared using the Mann-Whitney U test. The effect of implant length and crown-to-implant ratio on changes of marginal bone level were additionally determined. Out of 94 implants placed (47 test and 47 control), 78 implants (40 test and 38 control) were available for follow-up examination after 3 years of loading. One test implant was lost during the second year. Hence, implant survival was not significantly different between the two groups after 3 years (98% test; 100% control). We found no significant change of the crestal bone level from baseline to 3 y for test and control implants with $-0.19 \pm 0.62\text{mm}$ and $-0.33 \pm 0.71\text{mm}$, respectively. The inter-group difference was not significant. Crown-to-implant ratios were not associated with a statistically significant difference in marginal bone loss. However, the number of sites with pockets ≥ 5 mm was significantly higher in the test group. Based on the 3 y assessment, the use of 6mm implants can be considered a viable option when reconstructing posterior single tooth gaps.

Clinical Registration: DRKS00006290 ("Langzeitstudie zur Eignung von kurzen SLActiven Implantaten zur Versorgung von Einzelzahnrestorationen im Seitenzahngebiet -eine randomisierte klinische Studie")

Introduction

Constant efforts are aiming at the reduction of invasiveness of implant surgery. These have led to decreased patient morbidity, shorter surgical treatment time and a minimized risk of damaging neighboring anatomical structures (Thoma et al. 2015). Thus, there is a trend favoring the use of shorter implants, especially in cases with limited vertical bone dimensions.

The use of short implants however may implicate the risk of increased load on the peri-implant bone potentially resulting in enhanced loss of marginal bone or even in premature implant loss (Rossi et al. 2015, Anitua et al. 2014). However, whether a high crown-to-implant ratio may lead to a higher degree of occlusal load resulting in a negative influence on successfully-osseointegrated implants is controversially discussed (Chang et al. 2013).

A considerable number of clinical studies assessed implant survival rates as well as marginal bone level changes for short implants. Retrospective and prospective studies show survival rates of at least 92.2% after follow up periods between 2 and 7 years (ten Bruggenkate et al. 1998; Renouard and Nisand, 2005, Slotte et al. 2014). One of these clinical studies even reported on a success rate of 94.3% after an observation period between 1-6 years (ten Bruggenkate et al. 1998). However, in most of these studies the short implants were splinted with either short or long implants. One retrospective clinical trial reporting on 970 implants restored with single crowns in the maxillary molar region with lengths of ≤ 9 mm showed a cumulative survival rate over 84 months of 95.1% (Fugazzotto et al. 2004). There are also several studies reporting on short implants supporting removable dentures, thus limiting the validity of the outcome to that respective kind of loading.

There is only little data available for implants supporting unsplinted single crowns. However, the fact that short implants perform well when loaded with single crowns is based on data over short time periods only. Hence, there is a need for randomized controlled clinical trials comparing the outcomes of short and long implants supporting single crowns over long periods of time. Therefore, it was the aim of this randomized controlled clinical two-center trial to assess survival and marginal bone loss of 6 mm and 10 mm implants supporting single crowns in the posterior jaws. The null hypothesis was that implants of both lengths would perform similarly with regard to survival and change of marginal bone level.

Materials & Methods

This study was designed as a randomized, controlled two-center clinical trial (Appendix Fig.1). All procedures and materials were approved by the local ethics committee (StV Nr. 07/13). Eligible patients were informed in detail about the aim as well as possible risks and benefits of the study. Patients were free to refrain from study participation at any time point without the disclosure of a reason. All patients signed an informed consent before they were included in the study.

To meet the inclusion criteria, patients had to present themselves with a single tooth gap in the premolar or molar region of the upper or lower jaw and an existing antagonist (tooth or implant-borne reconstruction). The missing tooth had had to be extracted at least 6 months prior to implant placement. No periodontal probing depths (PPD) exceeding 5 mm in the residual dentition were accepted. A minimum of 2 mm of keratinized mucosa had to be present at the prospective implant site. Regarding bone dimensions, a minimal vertical bone height of 10 mm in the lower jaw (alveolar

crest to the mandibular canal), and 6 mm of bone height in the maxilla (alveolar crest to the sinus floor) were required. Internal sinus floor augmentation (modified Summer's technique) but no lateral guided bone augmentation procedures were allowed when placing the implants. All patients had to be systemically healthy.

Exclusion criteria comprised general contraindications against surgical interventions and smoking of more than 19 cigarettes per day (Lang and Tonetti 2003). The need for a preceding lateral bone augmentation with radio-opaque filler materials, prior therapeutic radiation of the jaw, severe bruxism or clenching habits as well as any mucosal disease except sporadic localized gingivitis were further exclusion criteria. Insufficient oral hygiene or inadequate compliance were additional reasons for exclusion.

Surgical Intervention

Implant placement was performed at two clinics at the University of Zurich by calibrated surgeons who were well-trained with the implant system. The randomization of the patients to either the test (6mm implant) or control group (10mm implant) was determined using a computer-generated randomization list (www.random.org). After administration of a local anesthetic (Septanest® 1:200.000, Septodont, Niederkassel, Germany or Rudocaine forte®, Streuli Pharma AG, Uznach, Switzerland) sulcular incisions at the adjacent teeth and a midcrestal incision were performed allowing to raise a full-thickness flap. At this stage, the randomization concealment was broken and the surgical site was prepared according to the

manufacturer's instructions (SLActive® standard plus soft tissue level implants, Straumann AG, Basel, Switzerland). The minimum primary stability had to reach 20 Ncm. All implants were covered with a healing cap. Flaps were closed with non-resorbable sutures (Supramid®, B.Braun Medical AG, Sempach, Schweiz or GoreTex® suture, Gore, Flagstaff, AZ, USA), leaving the implants for transmucosal healing. Patients had to refrain from brushing at the surgical site and instead had to rinse with a 0.2% chlorhexidine solution (Kantonsapotheke Zurich, Zurich, Switzerland) twice a day for one minute until suture removal. Analgetics (Mefenacid® 250/500 mg tablets, Kantonsapotheke Zurich, Zurich, Switzerland) were provided for optional intake during the first post-operative days. After a healing period of 6 to 10 days, sutures were removed. Three weeks later, oral hygiene was monitored, instructions for site-specific hygiene were repeated and supragingival tooth-cleansing was performed. Eight weeks after implant placement, impressions were taken using a standardized tray and a polyether impression material (Permadyne®, 3M ESPE, Rüschlikon, Switzerland). The impression of the opposite jaw was taken using alginate. No provisional restorations were inserted. Screw-retained porcelain fused to metal (PFM) crowns were incorporated with a torque of 35 Ncm. After insertion of the reconstruction a clinical examination (baseline) was performed measuring peri-implant and periodontal probing pocket depths, presence or absence of plaque and bleeding on probing at 6 sites per implant and the neighboring teeth. Additionally, a standardized x-ray was taken with parallel technique using an individualized x-ray tray (Fig. 1).

Follow up

After six months, oral hygiene was controlled and re-instructed if needed.

Thereafter, patients were recalled at regular intervals between 6 and 12 months for dental hygiene treatments according to their individual needs. At one year of loading and once every year thereafter, patients underwent a clinical examination of the study implant and the neighboring teeth. These appointments were conducted by one examiner per clinic and included measurements of peri-implant and periodontal probing pocket depths, presence or absence of plaque and bleeding on probing at 6 sites per implant and at the adjacent teeth. At these follow-up appointments technical failures such as chippings or loosening of abutment screws were recorded. Additionally, intraoral photographs as well as an x-ray applying the parallel technique using the above-mentioned individualized tray were taken.

History of periodontitis was determined as general attachment loss exceeding 5mm at more than 30% of the periodontal sites or tooth loss due to periodontitis.

Evaluation of x-rays

Digitalized x-rays of all implants were magnified tenfold and size-calibrated by their known length, width and inter-thread distance. Mesial and distal bone levels as well as the crown lengths were determined. Distances of the mesial and distal bone levels were measured in a right angle from the implant neck to the first visible bone-to-implant contact. (Fig. 2). These distances and the crown lengths were assessed using a shareware measuring software (ImageJ, Image J64, National Institute of Health, USA). Clinical lengths of crowns and implants were calculated by adding ~~4.8mm~~ of the supra-osseous part of the implant (composed by 1.8mm of machined implant neck and potential bone level changes from the nominal bone level at the margin of rough and machined implant neck of the standard plus implant type) to the measured (technical) crown length and subtracting that distance from the length of the whole implant.

When analyzing the bone level changes by regression analysis, we adjusted for the

baseline crown-to-implant ratio as one of the relevant confounders (Blanes et al. 2009).

All measurements were performed by two independent examiners who had previously been calibrated. Statistical analyses were performed with the average values of both examiners' measurements.

Statistics

In order to determine the minimal number of patients for the present study, a sample size calculation had previously been performed. To detect a potential difference in bone loss of 0.38 mm between the groups (Roccuzzo et al. 2010) with an assumed standard deviation of 0.5 mm for each group with a power of 80% at a level of significance of 5% after 10 years, a minimal sample size of 28 patients for each group was calculated. With regard to a planned follow-up period of 10 years a minimum initial number of 45 participants per group was considered reasonable.

Descriptive statistics included medians and interquartile ranges or mean \pm standard deviations (SD) for the ordinal and continuous variables. Categorical variables are presented as counts of total. Statistical analyses included comparison within test and control group at baseline and at the 3-year follow-up. Data from the x-ray measurements by the two different examiners were examined for concordance. A multiple linear regression model was fitted to marginal bone level change in order to assess the effect of implant length and crown-to-implant ratio, adjusted for the potential confounders smoking, history of periodontitis and bone level at baseline. P-

values below 5% were considered statistically significant. All analyses were performed with R (R_CoreTeam 2015).

Results

Initially, 96 patients could be included in the study. Two patients of the control group, however, did not receive the complete treatment according to the study (see Appendix Fig.1), thus being excluded from further assessment. At three years of loading, 81 patients could be re-assessed, whilst 13 patients did not show up for the appointments, skipped their recall due to personal reasons, or had moved abroad in the meantime. Out of the remaining patients 78 x-rays could be analyzed.

All patients were in good general health at the follow-up appointments. One implant from the test group got mobile during the second year of loading without any radiographically detectable marginal bone level change and had to be removed. All implants from the control group were still in place at the 3-year follow-up. This resulted in an overall survival rate of 98% for test and 100% for control implants. This difference was not statistically significant. No implant displayed peri-implantitis in terms of pocket depths > 5 mm in combination with suppuration and/or progressive marginal bone loss. The mean crown-to-implant ratio in the test group (1.48 ± 0.33) was significantly higher ($p < 0.001$) than in the control (0.86 ± 0.18).

Over three years the marginal bone level changed by -0.19 ± 0.62 mm (test) and -0.33 ± 0.71 mm (control). These values for the bone levels at baseline and at 3 years showed no statistically significant difference for each group. No significant inter-group

difference was found at 3 years (Fig. 3). For the assessment of distances on the x-rays, an inter-examiner correlation coefficient of 0.94% for differences < 0.1mm was calculated. A significantly higher number of implants with PPD of ≥ 5 mm was found in the test group ($p = 0.023$). These probing depths, however, had already been observed during the baseline examination and did neither show progression nor suppuration at any later time point (Table 1). Regression analysis of the changes of the marginal bone level at the 3-year follow-up showed a non-significant effect of implant length (estimated effect 0.38 for more bone loss for the long implants with $p = 0.152$) when adjusting for the set of potential confounders (smoking, history of periodontitis, bone level at baseline, crown-to-implant ratio, Table 2). With decreased initial bone level at baseline, regression analysis showed a distinct effect on future bone loss (see “Bone level at baseline” in Table 2). No chipping of the veneering ceramic occurred and loosening of the abutment screw happened in 3 cases.

Discussion

Based on the results of the three-year follow-up data, the hypothesis that implants of both lengths perform equally regarding survival and marginal bone level change was not refuted, as no statistically significant differences with regard to survival and bone level changes at three years of function were found

The survival rates of 98% (test) and 100% (control) of this study are slightly above the reported survival rates of previously published clinical studies ranging from 86.7 – 95.1% (Rossi et al. 2015); (Fugazzotto et al. 2004) at 5 and 7 years. A recently published 5-year prospective clinical study using an almost identical study design and implants of the same manufacturer with the same lengths reported slightly lower

survival rates of 86.7% for 6mm and 96.7% for 10 mm implants (Rossi et al. 2015). The marginal bone level change in that study was in accordance with the results of the present investigation. However, there are some relevant differences with regard to implant surface (SLA instead of SLActive), loading protocol (insertion of crown after 7 instead of 8 weeks) and supracrestal implant design (standard instead of standard plus). Likewise, the cohort in the above-mentioned study was slightly smaller and there were fewer smokers included. Furthermore, the study did neither report on the periodontal status of the included patients nor whether the patients had had a history of periodontitis.

In the present study the change of the marginal bone level ranged from 0.19 ± 0.62 mm (test) to 0.33 ± 0.71 mm (control) and did not show to be statistically significant. Similar results for marginal bone loss of 0.18 mm with similar standard deviations were reported in the previously mentioned study during the first three years of loading (Rossi et al. 2015). Hence, bone loss was below 0.2 mm for both groups and corroborates results from previously published data for the same type of implant (van Velzen et al. 2014, Filippi et al. 2013). Accordingly, the measured marginal bone level change is within the range of previously stipulated implant success criteria (Albrektsson and Isidor 1994, Ganeles et al. 2008).

Peri-implant probing depths of ≥ 5 mm in the test group demonstrated to be significantly higher in number compared with the control group. These probing depths however were already present at baseline and did not change during the observation period. As comparable information is missing from other clinical studies, it is difficult to estimate the importance of this finding.

Regarding short implants there is still a controversial discussion about the influence

of the crown-to-implant ratio on loss the of marginal bone level. While some studies and an older review pointed out that there might be no association (Tawil et al. 2006, Blanes et al. 2009, Schneider et al. 2012), more recent literature seems to indicate the opposite: A review article from 2014 addressed this issue and evaluated 7 retrospective and 6 prospective clinical studies and found a significant negative association between a crown-to-implant ratio of 0.6-2.36 and the marginal bone level (Monje et al. 2014, Garaicoa-Pazmino et al. 2014).

As a matter of course, the crown-to-implant ratio in the short implant group with 1.48 ± 0.32 were significantly higher than the ones of the control implants (0.86 ± 0.18). These values are very similar to those published in a similar study (0.54 for 10 mm and 0.96 for 6 mm long implants) by Rossi et al. 2015 (Rossi et al. 2015). Maximal crown-to-implant ratios of up to 2.2 reflect the fact that in some individuals of the study-population the remaining alveolar bone height was significantly reduced prior to implant placement, presumably as a consequence of preceding periodontal destruction. Crown-to-implant-ratio, however, turned out not to have an effect on implant survival or marginal bone level change as calculated by the regression analysis.

Crown lengths have been measured from the implant shoulder to the most coronal extension of the metal base of the crowns. It is most likely that the crown lengths were therefore slightly underestimated, as we thereby ignored the thickness of the veneering ceramic. There are two reasons for this approach: The functionally relevant crown length is determined by the location of the occlusal contact point. However, the latter can not exactly be determinable in the x-ray but is more likely to be located not on the tip or slopes of the cusps but close to the central fissure. Second, in some of our x-rays the extent of the veneering ceramic was not exactly determinable due to a radio-opacity being very close to the silicone of the

individualized x-ray splints. In order to rely on distances by clearly determinable end points we have therefor chosen the most coronal extension of the crowns' metal framework. Evident residual discrepancies were likely to be equaled out by applying the same method to both treatment groups.

The literature on implant success and survival suggests a negative association of survival and success when associated with a history of periodontitis (Mombelli et al. 2012, Heitz-Mayfield and Huynh-Ba 2009). No such relation could be found in the present study after three years. This might be due to the fact that the observation period is too short to detect peri-implantitis as the main biologic reason for implant failure (Jung et al. 2008, Roos-Jansaker et al. 2006, Jung et al. 2012).

The inclusion of smokers in the present study might be a limitation for the general validity of our findings, as an association of tobacco consumption and implant failure has previously been demonstrated (Heitz-Mayfield and Huynh-Ba 2009, Kasat and Ladda 2012, Strietzel et al. 2007). Although heavy smokers (> 19 cigarettes/d) were excluded from study participation, 20% of the patients in this study population were moderate smokers. Nevertheless, due to an equal smoker ratio in both groups, the inter-group comparison remains valid.

The present study aimed to compare the clinical performance of implants of different lengths. Clinical situations, where operators may be obliged to use short implants due to atrophic alveolar bone of limited height, short implants are most likely to be loaded with crowns of considerably greater lengths: in order to reach the occlusal plane these crowns will have to compensate for the bone resorption. This may lead to an additionally enhanced crown-to-implant ratio and thus might not show results equally to those found in the present study.

In conclusion, this RCT found no difference between test and control implants supporting single crowns in the posterior jaw at three years with regard to the primary outcome parameters survival and change of the marginal bone level. Technical complication rate was low measuring 3.8%, whereas no biological complications were observed.

Acknowledgements:

The clinical trial was supported by a grant by the International Team for Implantology, Basel, Switzerland (ITI Nr 517-2007). The authors received no further financial support and declare no potential conflicts of interest with respect to the authorship and/or publication of this article.

References

- Albrektsson T, Isidor F. 1994. Consensus report of session IV. In: Lang, NP & Karring, T, eds *Proceedings of the 1st European Workshop on Periodontology*. 365-369.
- Anitua E, Alkhraist MH, Pinas L, Begona L, Orive G. 2014. Implant survival and crestal bone loss around extra-short implants supporting a fixed denture: the effect of crown height space, crown-to-implant ratio, and offset placement of the prosthesis. *Int J Oral Maxillofac Implants*. 29(3):682-689.
- Blanes RJ. 2009. To what extent does the crown-implant ratio affect the survival and complications of implant-supported reconstructions? A systematic review. *Clin Oral Implants Res*. 20 Suppl 467-72.
- Chang M, Chronopoulos V, Mattheos N. 2013. Impact of excessive occlusal load on successfully-osseointegrated dental implants: a literature review. *J Investig Clin Dent*. 4(3):142-150.
- Filippi A, Higginbottom FL, Lambrecht T et al. 2013. A prospective noninterventional study to document implant success and survival of the Straumann Bone Level SLActive dental implant in daily dental practice. *Quintessence Int*. 44(7):499-512.
- Fugazzotto PA, Beagle JR, Ganeles J, Jaffin R, Vlassis J, Kumar A. 2004. Success and failure rates of 9 mm or shorter implants in the replacement of missing maxillary molars when restored with individual crowns: preliminary results 0 to 84 months in function. A retrospective study. *J Periodontol*. 75(2):327-332.
- Ganeles J, Zollner A, Jackowski J, ten Bruggenkate C, Beagle J, Guerra F. 2008. Immediate and early loading of Straumann implants with a chemically modified surface (SLActive) in the posterior mandible and maxilla: 1-year results from a prospective multicenter study. *Clin Oral Implants Res*. 19(11):1119-1128.
- Heitz-Mayfield LJ, Huynh-Ba G. 2009. History of treated periodontitis and smoking as risks for implant therapy. *Int J Oral Maxillofac Implants*. 24 Suppl39-68.
- Jung RE, Pjetursson BE, Glauser R, Zembic A, Zwahlen M, Lang NP. 2008. A systematic review of the 5-year survival and complication rates of implant-supported single crowns. *Clin Oral Implants Res*. 19(2):119-130.
- Jung RE, Zembic A, Pjetursson BE, Zwahlen M, Thoma DS. 2012. Systematic review of the survival rate and the incidence of biological, technical, and aesthetic complications of single crowns on implants reported in longitudinal studies with a mean follow-up of 5 years. *Clin Oral Implants Res*. 23 Suppl 62-21.
- Kasat V, Ladda R. 2012. Smoking and dental implants. *J Int Soc Prev Community Dent*. 2(2):38-41.
- Mombelli A, Muller N, Cionca N. 2012. The epidemiology of peri-implantitis. *Clin Oral Implants Res*. 23 Suppl 667-76.
- R_CoreTeam. 2015. R: A language and environment for statistical computing. <http://wwwR-project.org/>.
- Roccuzzo M, De Angelis N, Bonino L, Aglietta M. 2010. Ten-year results of a three-arm prospective cohort study on implants in periodontally compromised patients. Part 1: implant loss and radiographic bone loss. *Clin Oral Implants Res*. 21(5):490-496.
- Roos-Jansaker AM, Renvert H, Lindahl C, Renvert S. 2006. Nine- to fourteen-year follow-up of implant treatment. Part III: factors associated with peri-implant lesions. *J Clin Periodontol*. 33(4):296-301.
- Rossi F, Botticelli D, Cesaretti G, De Santis E, Storelli S, Lang NP. 2015. Use of short implants (6 mm) in a single-tooth replacement: a 5-year follow-up prospective

- randomized controlled multicenter clinical study. *Clin Oral Implants Res.*
- Schneider D, Witt L, Hammerle CH. 2012. Influence of the crown-to-implant length ratio on the clinical performance of implants supporting single crown restorations: a cross-sectional retrospective 5-year investigation. *Clin Oral Implants Res.* 23(2):169-174.
- Strietzel FP, Reichart PA, Kale A, Kulkarni M, Wegner B, Kuchler I. 2007. Smoking interferes with the prognosis of dental implant treatment: a systematic review and meta-analysis. *J Clin Periodontol.* 34(6):523-544.
- Thoma DS, Haas R, Tutak M, Garcia A, Schincaglia GP, Hammerle CH. 2015. Randomized controlled multicentre study comparing short dental implants (6 mm) versus longer dental implants (11-15 mm) in combination with sinus floor elevation procedures. Part 1: demographics and patient-reported outcomes at 1 year of loading. *J Clin Periodontol.* 42(1):72-80.
- Trindade R, Albrektsson T, Tengvall P, Wennerberg A. 2014. Foreign Body Reaction to Biomaterials: On Mechanisms for Buildup and Breakdown of Osseointegration. *Clin Implant Dent Relat Res.*
- van Velzen FJ, Ofec R, Schulten EA, Ten Bruggenkate CM. 2014. 10-year survival rate and the incidence of peri-implant disease of 374 titanium dental implants with a SLA surface: a prospective cohort study in 177 fully and partially edentulous patients. *Clin Oral Implants Res.*

Table 1. Baseline patient characteristics and outcome characteristics at the 3 year follow-up.

	6 mm implants	10 mm implants	p-value
Baseline characteristics			
Age (range)	52 (26;76)	58 (36;81)	0.295
Proportion m/f	19/22	17/23	0.728
Localization			
PM upper jaw	8	9	0.247
PM lower jaw	12	7	
M upper jaw	2	6	
M lower jaw	19	18	
Smoker ≤10cig/d	11	12	0.752
History of periodontitis	24	17	0.149
Plaque +	13	17	0.835
Probing depth > 5 mm	5	0	0.023
Bleeding-on-probing +	32	30	0.746
Recession (cases)	2	1	0.980
Crown-to-implant ratio	1.475 ± 0.326	0.858 ± 0.176	<0.0001
Bone levels [medians(iqr)] 0y	-0.18 (-0.56 to 0.01)	-0.18 (-0.67 to 0.13)	0.6282
Outcome characteristics			
Probing depth > 5 mm	5	0	0.023
Bleeding-on-probing +	32	30	0.746
Recession	2	1	0.980
Crown-to-implant ratio	1.744 ± 0.04	1.033 ± 0.028	<0.0001
Bone levels [medians(iqr)]			
1y	-0.39 (-0.80 to -0.02)	-0.39 (-0.76 to -0.02)	0.8932
2y	-0.13 (-0.77 to 0.07)	-0.35 (-0.88 to -0.04)	0.2168
3y	-0.38 (-0.87 to -0.06)	-0.58 (-1.13 to 0.07)	0.5449

m/f – male/female, PM – premolar, M – molar, cig/d – cigarettes per day, plaque+ - implant with plaque remnants

Chi-square tests were used for categorical variables, t-tests were used for ordinal and continuous variables, Wilcoxon test for bone level(iqr), Significant p-values ($p \leq 0.05$) are indicated with bold characters.

Table 2. Multiple linear regression model predicting bone loss.

P-values < 0.05 were considered statistically significant (bold numbers).

Variable	Estimated effect	Standard error	p-value
Implant length 10 mm (vs 6 mm)	-0.379	0.262	0.152
Smoking	-0.340	0.167	0.045
History of periodontitis	-0.101	0.148	0.499
Bone level at baseline	-0.793	0.120	<0.001
Crown-to-implant ratio	-0.448	0.304	0.144

Fig. 1 X-ray of test (left) and control (right) group

Fig. 2 Distance measuring concept on the standardized x-rays.

Fig. 3 Change in marginal bone level from baseline to 3 years.